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*Publication date:*  
2016

*Document Version*  
Peer reviewed version

[Link back to DTU Orbit](#)

*Citation (APA):*  
Binning, P. J., Trapp, S., Rolle, M., & Vezzaro, L. (2016). *Bringing modelling to life: current research in an introductory MSc modelling course*. Abstract from 5th DTU Biennial for Teaching and Learning, Lyngby, Denmark.

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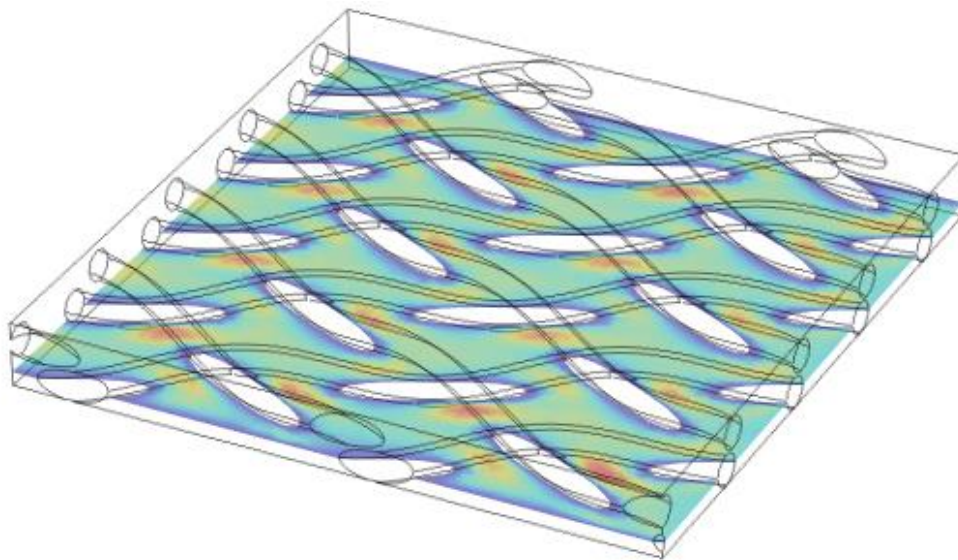
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## Bringing modelling to life: current research in an introductory MSc modelling course

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How do you take newly enrolled MSc students who have little experience with models, and bring them up to research standard in an introductory modelling course? The DTU course 12104 Modelling of Environmental Processes and Technologies is a 10 ECTS course that is a compulsory general competence course for all MSc in Environmental Engineering students (60-90 students). Typically the students have very limited modelling experience before starting the course. The curriculum contains 6 main elements: Models based on analytical solutions and programming; statistics; aqueous geochemical modelling; ordinary differential equations; partial differential equations; and model parameter estimation, sensitivity and uncertainty analysis. The central element of the course is 5 assignments which are new every year and address current research being conducted at the Department.

An example assignment is shown in figure 1. In the assignment, students calculate the velocity and pressure fields in between two membranes using the program Comsol Multiphysics. The assignment was run in October/November 2016 and is based on research currently being conducted by a PhD student in the Department in collaboration with the company Aquaporin.



**Figure 1.** Velocity field between two membranes, separated by a woven mesh spacer in an Aquaporin reverse osmosis membrane, as calculated in a student assignment using Comsol Multiphysics.

The course employs flipped learning. This means that each assignment is given to the students first, then the students are given tutorials to help them get started. Finally, short focussed lectures and readings provide then with the theoretical background they need to solve the problem.

Often the assignments later evolve into research papers or usable products. An example was published by Aisopou et al. (2015) who describe a model that is now also being used by the Danish EPA in their risk assessment tools (<http://mst.dk/virksomhed-myndighed/jord/screeningsprincip-for-jordforurening/>). The model described in these publications/tools was originally developed in 2012 as an assignment for the 12104 course and only later published and polished into a product that is now being used by industry.

The course is expensive to run because of the time needed to develop the new assignments. A few principles guide the selection of assignment topics:

- The lecturers pick problems that are currently being worked on. So time spent developing assignments is actually time invested in your own research.
- We often couple the assignments to the work of PhD teaching assistants involved in the course. If they are going to teach, why not get them to teach on something related to their own work?
- We never invest in new assignments unless we can see a potential spin-off.

There are many direct research benefits of running a course in this way. You have many people looking at a problem and this provides new insight: the students are extremely good at finding deficiencies in problems and holes in solution approaches. The development of a new assignment forces the lecturer to simplify the problem sufficiently so it can be done, sharpening their own understanding of the problem. The use of current and new problems each year means that the course is 'alive': Each year is different and so staff are heavily engaged in the course.

The key to enabling the students to work on such problems is the use of tutorials that are closely related to the problem described. For the example shown in Figure 1 students first do tutorials on Couette flow and the Von Karmen vortex street, in each case following a guided 'toolbox' that allows them to construct a model before answering a series of questions on the problem. Complete answers are provided. Students work on the assignments in groups of 4 students. The groups are assigned for the first assignment, with mixed international/DK students, improving integration of newly enrolled students. After the first assignment students freely choose their own groups, but more than half elect to continue in the assigned groups. The staff provide hands-on assistance so the students can solve the problems.

The expectation of the course is not that the students become modelling experts. Rather, the students should be inspired and have seen a broad pallet of the commonly used modelling techniques employed in Environmental Engineering. Many of the students go on to work with models in subsequent courses and their thesis. But some do not, and then their only modelling experience is through the course.

The examination of the course consists of an evaluation of the 5 group assignment submissions and an oral exam where the group presents one of the assignments and the examiners pose individual questions to the students. The exam is video-taped and sent to an external examiner for evaluation. The video-taped presentations are subsequently provided to future students to inspire them.

As a coordinator, the most important reflection on the course is the balance between the time invested in the development of new course material every year and the course outcomes. From the students point of view, the investment is clearly appreciated. When evaluating the course, the students are very positive about the assignments and the direct link to research. They also like the problem-centred approach of the course. They highlight the enthusiasm and engagement of the lecturers who are (like the students) often struggling to come to terms with the new problems. For the staff involved, the benefits extend far beyond the pleasure of experiencing the excitement of the students. It is enormously satisfying to look at research papers and products developed by the Department and know that they started life as a student assignment in the course 12104.

For the Undervisningsbiennale, discussion will be held on how to activate research in teaching, how to design an appropriate course form to achieve course learning outcomes, how research can be employed in courses in a cost effective manner etc.

## References

Aisopou, Angeliki , Poul L. Bjerg, Anne T. Sonne, Nicola Balbarini, Louise Rosenberg and Philip J. Binning, Dilution and volatilisation of groundwater contaminant discharges in stream, *Journal of Contaminant Hydrology*, **172**, 71-83. 2015.